Waking a Sleeping Giant: The Tobacco Industry's Response to the Polonium-210 Issue

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The major tobacco manufacturers discovered that polonium was part of tobacco and tobacco smoke more than 40 years ago and attempted, but failed, to remove this radioactive substance from their products. Internal tobacco industry documents reveal that the companies suppressed publication of their own internal research to avoid heightening the public's awareness of radioactivity in cigarettes. Tobacco companies continue to minimize their knowledge about polonium-210 in cigarettes in smoking and health litigation. Cigarette packs should carry a radiation-exposure warning label. (*Am J Public Health.* 2008;98:1643–1650. doi:10.2105/AJPH.2007.130963)

Although it has been known for more than 4 decades that tobacco smoke contains the radioactive substance polonium-210 (PO-210), publicity surrounding the poisoning of former KGB agent Alexander V. Litvinenko with PO-210 in 2006 has heightened awareness of its presence in tobacco smoke.[1,2] We reviewed internal tobacco industry corporate records made public through litigation to assess cigarette manufacturers' internal and external activities in response to the presence and potential health effect of PO-210 in cigarettes.

Documents show that the major transnational cigarette manufacturers managed the potential public relations problem of PO-210 in cigarettes by avoiding any public attention to the issue for fear of "waking a sleeping giant."[3] Despite the industry's long-time strategy of "creating doubt about the health charges without actually denying it,"[4] internal corporate records suggest that manufacturers avoided drawing attention to the PO-210 issue in the public domain. Documents also show that once manufacturers determined that PO-210 was a constituent of tobacco smoke, they attempted, but failed, to remove it. Simultaneously, internal research potentially leading to advancements in scientific knowledge was avoided. Similarly, internal experimental results favorable to the tobacco companies were suppressed from publication by company lawyers despite urgings by internal scientists contending that their data contested reports published in the medical literature. Currently, although all the major tobacco companies would likely admit that PO-210 is present in their products, they continue to minimize its importance in smoking and health litigation and remain silent on the issue on their Web sites and in their messages to consumers.

METHODS

We analyzed internal corporate documents produced in response to litigation involving the major tobacco manufacturers. The history and public availability of these records were previously described.[5–9] We searched documents produced by British American Tobacco, which is based in the United Kingdom, at the British American Tobacco Document Archive Web site (http://bat.library.ucsf.edu). We searched the major US tobacco manufacturers' documents, trial testimonies, and deposition transcripts in collections housed at the Legacy Tobacco Documents Library (http://legacy.library.ucsf.edu). We also searched documents housed at British American Tobacco's document depository in Guildford, England.

We conducted online searches between 2005 and 2007 with a snowball search technique,[10] initially combining terms such as polonium, PO-210, radioactivity, Chernobyl, PB-210, and lead-210. We also conducted searches of the names of internal technical research projects and personnel working in research divisions within each company. We analyzed approximately 1500 relevant documents to create a historical and thematic framework. The limitations of using internal tobacco company records as research data have been previously described.[11,12]

SOURCES OF POLONIUM-210

In 1964, PO-210 was reported to be a tobacco smoke constituent.[13] PO-210 emits a carcinogenic form of radiation called alpha radiation.[14,15] Inhalation experiments showed PO-210 to be a cause of lung cancers in animals.[16,17] PO-210 is thought to deposit in the bronchial segmental bifurcations, resulting in substantial doses of high-energy alpha radiation in the pulmonary sites where bronchogenic carcinomas frequently arise.[18,19] Alpha radiation has also been shown to induce signaling pathways in cells that are not directly exposed (the so-called bystander effect).[20] Mean tissue concentrations of PO-210 in cigarette smokers have been observed to be more than double those of nonsmokers.[21] It is estimated that smokers of 1.5 packs of cigarettes a day are exposed to as much radiation as they would receive from 300 chest X-rays a year.[14] PO-210 has been estimated to be responsible for 1% of all US lung cancers.[22] Therefore, given that each year an estimated 162 460 deaths in the United States[23] and 1.3 million deaths worldwide[24] are attributable to lung cancer, PO-210 may be responsible for more than 1600 deaths in the United States and 11 700 deaths in the world every year.

Although the atmosphere contains PO-210 arising from radium-226 that occurs naturally in the earth's crust,[25] the majority of the PO-210 in tobacco plants likely comes from high-phosphate fertilizers applied to the tobacco crop.[26,27] Tobacco farmers in developed countries primarily use manufactured fertilizer high in phosphates produced from apatite rock that contains radium-226 and descendant radioisotopes such as lead-210 and PO-210.[18,28] Tobacco is a unique

agricultural crop in that its flavor depends on nitrogen reduction, which occurs through the repeated application of high-phosphate fertilizers.[28] The higher the phosphate level of the fertilizer, the higher the concentration of PO-210 in the tobacco plant.[18] Tobacco grown in certain developing countries has approximately one third less radioactivity than tobacco grown in developed countries,[25] and the radioactivity of tobacco grown in the United States has increased over time.[26]

As high-phosphate fertilizers are applied to tobacco crops, PO-210 is absorbed from the soil through the plant roots.[26] PO-210 also deposits on the surface of the tobacco leaf via fine, sticky hairs (trichomes), which bind airborne radioactive dust particles generated during the application of fertilizers.[29] PO-210 is thought to be encapsulated with calcium phosphate and lead-210 into insoluble radioactive particles, which are subsequently transferred directly into the mainstream smoke (the smoke that is inhaled directly into smokers' lungs).[29,30]

EFFORTS TO REMOVE POLONIUM-210

During the 1960s, the major tobacco manufacturers determined that PO-210 was a constituent of tobacco and tobacco smoke.[31–37] By 1968, Philip Morris had verified that the levels of PO-210 in its cigarette brands were similar to what had been reported in the literature at the time (0.33–0.36 picocuries per gram [pCi/g] of tobacco materials contained in a cigarette).[38]

After confirming PO-210 was in tobacco and tobacco smoke, the tobacco industry sought to remove PO-210 from its products but ultimately failed to substantially reduce its concentration in the tobacco leaf. These efforts primarily included washing tobacco leaves, selectively measuring PO-210 in tobacco stock prior to manufacturing commercial cigarettes, filtering mainstream smoke, and employing genetic engineering techniques to reduce leaf radioactivity.

Washing Tobacco Leaves

In documents from the mid-1970s, Philip Morris reported it could use certain nonpolar solvents to wash PO-210 from the tobacco leaf to reduce leaf radioactivity by 10% to 40%.[39–41] Former Philip Morris scientist William Farone testified in 2001 about Philip Morris's washing efforts:

> We tried a methodology to remove polonium 210 from the tobacco. One of the researchers working for me spent quite a bit of her career attempting to do that, and we found that we could wash off the tobacco that Philip Morris obtained about half. The other half was inside the tobacco. So it's hard to wash it off. And it's difficult to consider how you would go about washing all the tobacco that came into Philip Morris.[42]

Liggett Tobacco Group acknowledged that solvents used to wash the tobacco leaves also caused "removal of most of the aromatic flavorants which give tobacco its characteristic and desirable aroma."[43] Liggett's assistant director of research concluded that washing the tobacco leaf was not commercially advantageous given the loss of aromaticity coupled with the realization of scant health benefit: "[I]t has been our feeling that the disadvantages with respect to economics and loss in flavorants outweigh the advantages of marginally reduced biological activity for this type of process."[44]

Selectively Measuring Polonium-210 in Tobacco Stock Before Production

Philip Morris established a laboratory in the early 1980s to selectively monitor tobacco for low-level radiation arising from PO-210. Former Philip Morris scientist Farone testified in 2001 that an alternative to washing the tobacco to remove PO-210 was to selectively monitor tobacco that would be incorporated into the company's cigarettes.[42] Farone also testified in 1999,

> [T]he idea here was, "Okay. We can't control the fertilizer and what the farmers apply, but what we can do is measure the product that we're using to make sure that the radioactivity is very low, beyond some low level. So at the end of 1981, around '81, we set up—Dr. Rosene's [*sic*; Dr. Osdene's] group actually did, a low level laboratory to measure whether or not some of the materials used in tobacco products were radioactive, and started making some measurements, and according to information I received from Dr. Rosene [*sic*; Dr. Osdene], he removed from the production stream certain materials that he felt were too radioactive to be use [*sic*] in making cigarettes.[45]

Publicly available documents do not clarify whether other cigarette manufacturers also monitored PO-210 content in cigarettes. However, records show that the majority of the companies monitored or had plans to monitor radiation levels in crops purchased during the mid-1980s in response to the Chernobyl disaster.[46–48]

Retired Philip Morris vice president of research, development, and engineering Richard Carchman also testified that one of Philip Morris's responses to queries about knowledge of PO-210 in cigarettes was to create a low-level radiation measurement laboratory.

> Q. And did that cause Philip Morris to take any action [regarding the PO-210 issue]?
> A. When you say radioact—yes, it did. I'm sorry. Yes, it did. And what we did was, first of all, when you say radioactive, this is not like going around with a Geiger counter and watching it click. This is a very low level of radioactivity. So we developed the first low level radioactive laboratory to measure Polonium-210. It's found in very, very low levels. It was very, very hard to measure, but we established this laboratory to actually measure it.
> Q. And were you able to measure it?
> A. It's in tobacco. It's in tobacco smoke.[49]

Farone testified in 1998 that Philip Morris closed its low-level radiation measurement facility because it was producing results that might jeopardize the company in smoking and health litigation,[50] meaning that plaintiffs could show that the company had the means to produce a safer cigarette but chose not to do so.

Filtering Mainstream Smoke

Efforts to filter and remove PO-210 from cigarette smoke began in the 1960s, although documents show that none of the filters tested removed substantial amounts of PO-210.[51,52] In addition, documents suggest that to eradicate PO-210 via cigarette tip filters, particulate matter containing tar and nicotine also needed to be removed.[53,54] Former Philip Morris chemist Jerry Whidby testified in 2002 that "the general reduction scheme of reducing tar and nicotine also reduces polonium-210."[55]

After testing a tourmaline filter (Jacobson's filter), R.J. Reynolds concluded that the filter did "have a small effect in the removal of polonium-210."[56] Further, R.J. Reynolds scientist Charles Nystrom reported,

> The tourmaline filter reduced both the polonium-210 and solids in the smoke by about 30% when compared with control WINSTONS. The results indicate that reports of a reduction of polonium-210 in smoke by Jacobson's tourmaline filter may very likely be explained by the higher filtration efficiency of the filter for solids in the smoke and not due to a specific removal of polonium-210 from the smoke.[51]

The company concluded from Nystrom's finding that it was "difficult to see how a tourmaline filter could be useful in an advertising campaign. It is recommended that we express no interest in this idea."[51]

R.J. Reynolds also tested an ion-exchange resin filter in 1967 and found it to be ineffective at removing PO-210 in smoke.[52] At British American Tobacco, work began as early as 1966 to remove PO-210 with copper-treated filters, but British American Tobacco researchers found the filters to be ineffective at the desired copper concentration.[57] British American Tobacco scientists concluded that although there might be "a slight selective removal of polonium-210," the "effect, if significant, is too small to be useful."[58]

Philip Morris appeared to have the most success with cellulose acetate filters in 1976. The company observed that the filter removed 40% to 50% of PO-210 from smoke.[59] However, these filters did not remove "appreciable quantities" of the insoluble fraction of PO-210 and only 50% of the soluble fraction.[60] This finding is significant because it is the insoluble radioactive particles that are thought to be deposited in the lung.[29,30]

In the early 1980s, R.J. Reynolds again looked into filtering methods to remove PO-210 and lead-210 from cigarette smoke. After evaluating patented technology to remove these substances from tobacco and tobacco smoke, a R.J. Reynolds scientist recommended that the company not pursue this technology because of its unlikely commercial success and the harmful effects of introducing various caustic additives.

> Obviously, the methods suggested would be extremely difficult to implement on a commercial scale basis. Also we have no way of estimating the potential deleterious effects of the materials suggested, i.e., hydrogen peroxide, nitric acid, etc., for removal of the lead-210 and polonium-210 on the tobacco.[61]

Reducing Leaf Radioactivity by Genetic Engineering

Former Philip Morris scientist Farone testified in 2001 that the company undertook a genetic modification project to prevent uptake of PO-210 by tobacco plants.

> [W]e had a program, an extensive program, to do genetic modification of tobacco. One way to keep the polonium from getting inside the tobacco is to genetically select strains of tobacco that will not what we call deposit . . . [W]e undertook a program with Crop Genetics International to do two things. One was to look for a tobacco that wouldn't take up the polonium. And also, with regard to making it easier to wash the tobacco . . . the idea is to have strains that have a smoother surface so that dust and things like that won't stick on the surface. All of these programs—I don't want to take the time to go through them all, but basically they were instituted with the idea that the results of these could be used to lower the biological activity of the cigarettes.[42]

During the same trial, Farone was asked whether Philip Morris continued (up until 2001, the date of the testimony) to sponsor genetic modification work aimed to reduce PO-210.

> A. Well, it was shut down before the total results were in. So what happens is we have a cycle where it's funded, and then a shutdown, and then it's funded and then shut down. And that's . . . paralysis by analysis. The idea is to extend the length of time that products that kill people stay on the market.
> Q. Philip Morris is still doing genetic engineering of its products today?
> A. Not still. Philip Morris is doing genetic engineering of its products today after having started, stopped, started, stopped, started, stopped.[62]

TOBACCO INDUSTRY SUPPRESSION OF POLONIUM-210 RESEARCH

Refusal to Publish Research and Fear of Liability

Lawyer-directed control, suppression, and, in some instances, spoliation of internal tobacco industry smoking and health research for fear of litigation liability has been described in the academic literature and in judicial proceedings.[8,63–66] In *United States v Philip Morris*, Judge Gladys Kessler, who, in August 2006, found the major tobacco companies guilty of violating certain provisions of the US RICO statute (Racketeer Influenced and Corrupt Organizations Act),[67] summarized the tobacco industry's conduct related to suppression of information:

> [Tobacco company] defendants attempted to and, at times, did prevent/stop ongoing research, hide existing research, and destroy sensitive documents in order to protect their public positions on smoking and health, avoid or limit liability for smoking and health related claims in litigation, and prevent regulatory limitations on the cigarette industry.[68]

Internal documents relevant to the industry's internal PO-210 research also show that lawyers played a substantial role in suppressing information with the aim of protecting companies' legal position. For example, a 1985 R.J. Reynolds attorney document stamped "privileged and confidential" related to the legal department's involvement in denial of publication of internal research involving PO-210 research stated,

> The Law Department and R&D [Research and Development] management have on some occasions denied permission to publish some research results. These denials were, in some instances, the result of competitive concerns . . . and, in others, an unwillingness to draw attention to topics that could be considered problematic of the Industry from a smoking and health standpoint. . . . Polonium research. Stewart Bellin [in-house R.J. Reynolds scientist in the Biological Research Division] reported that he was upset about the Company's denial of publication of his polonium research in 1967. Bellin, along with Dr. Nystrom [section head of R.J. Reynolds' Biological Research Division], had authored a paper concluding that the presence of polonium in tobacco was a result of atmospheric pollution and not uptake from soil.[69]

Beginning in 1967, the Center for Tobacco Research (CTR) made a financial commitment to conduct an analysis of published literature relating to PO-210 through Special Project 48.[70] Special projects were research projects funded by CTR and directed by the general counsels of Philip Morris; R.J. Reynolds; Lorillard; Liggett; Brown and Williamson; and American Tobacco, as well as external lawyers, specifically commissioned for possible use in litigation.[71] The attorney's notes regarding Special Projects indicated that (1) initially attorney David Hardy of Shook, Hardy, and Bacon denied a polonium literature search proposal by CTR's general counsel because the information was otherwise available, (2) CTR was delayed in responding to requests for publications, and (3) the center requested substantive changes in the text of resulting publications. The attorney's notes

also say, "Council retains the privilege of reviewing and commenting upon all manuscripts prepared for publication and of exercising a limited control over the timing of their release."[70]

Philip Morris documents show that the majority, if not all, of the company's internal reports regarding PO-210 were not published.[72,73] One manuscript believed by some Philip Morris scientists to be favorable to the tobacco industry and to refute extant literature was withheld from publication for fear of heightening public awareness of PO-210. A Philip Morris document deprivileged in the 1998 Minnesota litigation titled *Review of Philip Morris Scientific Documents* stated,

> Polonium-210. Research during the 1970s found that Martell's [who published PO-210 concentrations in cigarettes] values were far too high, but publication of research was denied in order to avoid raising controversy again.[74]

In 1978, Philip Morris scientists developed a manuscript titled *Naturally Occurring 222 Radon Daughters in Tobacco and Smoke Condensate*, written by Philip Morris researchers Robert Jenkins, Roger Comes, Margaret Core, and Thomas Osdene with Robert Tucci and Thomas Williamson of the University of Virginia.[75] They concluded that (1) soluble and insoluble radioactive particles were present in mainstream smoke and PO-210 concentrations were "2 to 3 times lower" than published values and (2) the reported procedure for calculating the dose delivered to smokers was invalid.[75]

Documents show that some Philip Morris scientists strongly urged the company's legal counsel to publish the 1978 Jenkins paper, because they believed their work genuinely refuted published work and that the company would benefit politically from the results. Vice president of research and development R.B. Seligman wrote to Philip Morris general counsel Alex Holtzman to urge publication of the Jenkins report:

> To briefly restate my position, I believe we should publish the article to set the records [*sic*] straight concerning 210 PO levels in smoke. . . . We would be publishing information that is already in the literature; however, we would be correcting the spurious quantitative data published by Martell.[76]

Other Philip Morris scientists contended that the work should not be published. Paul Eichorn of Philip Morris wrote to Seligman, "Dr Gannon [Phillip Morris] has questioned doing so [publishing] and I do too. It has the potential of waking a sleeping giant."[3]

In fact, Walter Gannon wrote to Eichorn that even though Philip Morris could report lower levels of PO-210 in smoke than were reported by Martell,[29] the reality that PO-210 was present in cigarette smoke would, in itself, be damaging to the company.

> This project was begun when I was manager of the Chemical Research Division. However, since that time I have had some concern as to whether the results of this work should be published. These doubts remain. The Martell controversy seems to have dimmed in the public eye. To publish this work now might resurrect the whole issue. . . . The fact that we have shown the levels to be 2–4 times lower than Martell's work indicates does not mitigate the overall conclusion. . . . If we could show that there is a threshold value below which no physiological damage could possibly occur, then I would have fewer qualms about publishing this paper. However, this issue remains moot and the fact that we admit that Martell was essentially correct could be damaging.[60]

Philip Morris's director of development, Richard Thomson, also stated, in a handwritten note to Eichorn, "I have some doubts in my mind whether we should publish in this area."[77]

Documents show that Seligman's request to publish Jenkins's manuscript was repeatedly denied. In a 1980 letter to Philip Morris counsel Holtzman, Seligman again urged the attorney to allow publication of the work on PO-210:

> I would like to support . . . [Jenkins's] plea for publication of the data we generated some years ago. If you recall, when we requested publication, we felt this was an important contribution to the literature because our data did refute the values reported by Martell. Permission was refused at the time, much to our disappointment. Perhaps that decision should be reconsidered. We have done a definitive study using expertise that has not been demonstrated anywhere in the literature. Ours is a technically sound piece of work which will stand scrutiny by any peer review group, and to repeat, it would cause the data previously generated by Martell to be questioned.[78]

After meeting with a scientist from the US Department of Agriculture, British American Tobacco also reported that "Philip Morris would not be publishing any of their work [on polonium] for legal reasons."[79]

In June 1982, at the request of then director of research and vice president of science and technology at Philip Morris Osdene, Jenkins reviewed an article Martell had submitted to the *Proceedings of the National Academy of Sciences*, titled *The Alpha Radiation Dose at Bronchial Bifurcations of Cigarette Smokers Exposed to High Indoor Radon Progeny Levels*. In his review, Jenkins again urged Osdene to publish his own 1977 work for Philip Morris as well as "openly support independent researchers . . . with a free hand to publish their results."[80] Jenkins went on,

> The only way to ever address these types of hypothetical papers is by the publication of proper and correct scientific results. At present, the major funding support for any research along these lines is from the anti-smoking forces. The tobacco industry has chosen not to answer these types of studies with well conducted scientific research, but has chosen to remain quiet in hopes "it too shall pass." As we have constantly seen since 1964, it continues to make news. The worst part being that there may be some degree of validity amonst [*sic*] the many assumptions that are grossly incorrect.[80]

Finally, a 1997 report from Andrew Frisch in research and development to Cathy Ellis, then senior vice president of his department, indicates that the request to publish the 1978 Jenkins study was denied.[81] Handwritten marginalia on the document, found in Ellis's files, read, "Publish it *now*! Call in Jenkins and *submit*."[82] To our knowledge Philip Morris never published this report.

Inside British American Tobacco, researchers may have also been restrained from publishing their PO-210 research. For example, handwritten notes from R.B. Richardson of British American Tobacco to his research and development colleague C.I. Ayres in 1985 read, "Attached is a draft report on polonium-210 which I wrote some time ago. I have not done any more work on it, as it seems obvious that it will never see the light of day."[83]

Closure of the Philip Morris Polonium-210 Monitoring Laboratory

Former Philip Morris scientist Farone testified in 2002 that Philip Morris closed its low-level radioactivity facility because of product liability concerns. Responding to the question of whether Philip Morris studied the "polonium problem," Farone stated,

A. [Polonium] was considered to be a low-percentage problem. For example, something less than ten percent . . . of the disease might be caused by organic compounds, and maybe only ten percent of that was due to polonium—so only one percent of the problem. However, it was something that was very easy to take care of, because all you had to do was measure the tobacco and make sure that the radioactivity of what you were using was not any higher than the background levels of radioactivity like was in this room. So you would be convinced that you weren't exposing people to elevated levels of radioactivity.
Q. And what happened to that project?
A. Well, we actually built a facility around 1981, '82. It was commissioned, put in service, and the measurements were being made. And at the time I left, they were still being made. The facility was terminated somewhere in about 1986.
Q. Do you know why?
A. Yes, I do.
Q. Please tell the jury.
A. Because it was producing evidence that could compromise the company in litigation such as this.[50]

Farone testified in 1999 not only that Philip Morris closed the facility but also that Philip Morris's Osdene had reported successfully removing certain tobaccos from the manufacturing process that had elevated PO-210 levels.[45]

Avoidance of Studies on Polonium-210 Retention in Smokers' Lungs

Internal tobacco industry documents suggest that although the companies undertook efforts to determine levels of PO-210 in tobacco and tobacco smoke, only British American Tobacco and the German cigarette industry conducted limited studies of PO-210 retention in the lungs of smokers.[84] In 1985, British American Tobacco used 1 smoker and 12 cigarettes to conclude that PO-210 retention (mean retention of 40%) was slightly lower than but similar to the lung retention of total particulate matter (tar and nicotine) from inhaled mainstream smoke.[85] British American Tobacco concluded that even though it could better determine true PO-210 lung retention values, it planned to refrain from further research and would keep abreast of other research produced in this area.[85]

Internal Philip Morris documents suggest that as long as the company could avoid having knowledge of biologically significant levels of PO-210 in its products, it could ignore PO-210 as a possible cause of lung cancer. For example, a 1982 document from Osdene, former director of research and vice president of science and technology at Philip Morris, to former Philip Morris chief executive officer Hugh Cullman and Philip Morris's general counsel Holtzman suggested that as long as a biologically significant PO-210 dose delivered to smokers remained unknown, "any suggestion of a cause and effect relationship between exposure to alpha particles from PO-210 and other sources and the occurrence of malignances in any tissues is spurious and unsubstantiated."[86]

Despite the encouragement of Philip Morris's own consultant to assess PO-210 retention in smokers' lungs,[87] no publicly available internal documents contain evidence of human or animal research carried out at Philip Morris to evaluate PO-210 retention in the lung. Conceivably, such documents might have been destroyed or protected from disclosure by privilege claims. It is well known that Philip Morris's Osdene directed biological experiments on nicotine addiction and carcinogenesis induced from cigarette smoke in Philip Morris's offshore laboratory INBIFO (Institut Fur Biologische Forschung) in Cologne, Germany, to avoid discovery in US litigation.[64] Philip Morris's consultant Alfred Wolf[88,89] urged the company to conduct animal research to determine PO-210 retention in the lung and wrote,

> [A] policy of retrenchment every time something new appears in the literature or the "press" must be costly. . . . A more aggressive policy of research into all facets of smoking using all tools that can be mustered will surely be less expensive and more satisfying and stabilizing in the long run.[90]

TOBACCO INDUSTRY RESPONSES IN SMOKING AND HEALTH LITIGATION

Although tobacco manufacturers have known since the 1960s that tobacco and tobacco smoke contain PO-210, they have minimized that knowledge in smoking and health litigation. First, Philip Morris's senior executives have denied or avoided having to admit to a substantive knowledge of the presence of PO-210 in its products. In a 1997 deposition, Geoffrey Bible, Philip Morris chief executive officer (1994–2002), stated that he did not know that PO-210 was in his company's Marlboro brand. Bible worked at the company from 1968 to 1970 and from 1976 to 2002, years in which Philip Morris's research on PO-210 was conducted, but claimed ignorance of PO-210 content in cigarettes:

> Q. Do you know when you smoke a Marlboro, that you may be taking in radioactive substances in your body?
> A. No, I didn't know that.
> Q. Have you ever heard of polonium 210?
> A. I think I have, yes.
> Q. Do you know that polonium 210 is a contaminant of tobacco?
> A. No, I didn't know that.[91]

Similarly, Osdene, former director of research and vice president of science and technology at Philip Morris, who ran the low-level PO-210 measurement laboratory at Philip Morris,[92] refused to respond to questions regarding PO-210 during a 1997 deposition taken by plaintiffs' counsel in the seminal Minnesota tobacco litigation. Osdene, who was at the time a subject of a Justice Department inquiry into fraud perpetuated by the tobacco manufacturers, invoked his Fifth Amendment privilege against self-incrimination 123 times.

> Q. Polonium 210 is a radioactive substance, is it not, sir?
> A. Same response. [On advice of counsel, I respectfully decline to answer based on my Fifth Amendment privilege against self-incrimination because there is an ongoing parallel criminal investigation.][93]

Further, Nick Brookes, chairman and chief executive officer of Brown and Williamson (1995–2000), who had previously been with British American Tobacco since 1978 and acted as 1 of the 5 regional directors of British American Tobacco, also denied knowledge in a 1997 deposition:

> Q: [A]re you aware that polonium is a radioactive substance?
> A: It sounds like one, but I'm not directly aware that it is.[94]

An undated Brown and Williamson document outlined prepared responses for the company's expert witnesses on several topics, including carbon monoxide and nicotine levels in cigarettes. Regarding PO-210, Brown and Williamson lawyers were willing to allow expert witnesses to admit there were trace

amounts of PO-210 in its products, but directed them to assert that PO-210 posed no health risk to smokers:

> Expert Witness Deposition Outline
> Tobacco Smoke Constituents
> Points to be made:[95]
>
> Although Polonium 210 (210PO) has purportedly been established as tumorigenic to laboratory animals, no reasonable connection has been drawn between the 210PO content of tobacco or tobacco smoke and human carcinogenic activity. In fact, the level of 210PO to which smokers are exposed is clearly too small to affect the health of smokers.
> Admission. The trace amount of Polonium 210 in tobacco and tobacco smoke is not a source of danger to smokers.[95]

A second tactic the tobacco companies have used to avoid the PO-210 issue in smoking and health litigation is to attribute PO-210's incorporation into tobacco to natural phenomena that are out of the manufacturer's control. R.J. Reynolds recognized the potential of this defensive strategy in the early 1960s:

> In addition to the potential value of a marketable cigarette low in polonium-210, any evidence showing that atmospheric alpha activity could be a major factor in the genesis of lung cancer could become of value to the Company from a legal point of view in law suits brought against the Company by lung cancer victims.[96]

In the 1999 trial testimony of Carchman, the retired Philip Morris vice president of research, development, and engineering emphasized that PO-210 is everywhere and that it could even be in the court room where he was on the witness stand.

> Q. How about Polonium-210? . . . How does polonium, which sounds like a radioactive—is polonium radioactive?
> A. Polonium-210 is radioactive.
> Q. How does it get into tobacco?
> A. It's another one of those things that's everywhere. You had Chernobyl, in Russia, blew a lot of Polonium-210 in the air. It settles down everywhere. I'm sure if you came in with the right kind of machine, we could measure Polonium-210 in this room. So anything that grows outside is going to have Polonium-210 on it. Tobacco grows outside; it does have Polonium-210.[49]

Carchman put forward the same argument in another 1999 trial:

> Q: Where is polonium 210 found?
> A: Everywhere . . .
>
> Q: How is it that polonium 210 comes to be in tobacco smoke?
> A: Tobacco plants grow in the environment and it's really—the environment. Primarily because of nuclear fallout, things like Chernoble [*sic*], that polonium 210 sort of drops from the sky onto lots of things, including tobacco.[97]

CONCLUSIONS

The tobacco industry was clearly concerned about the effect that a widespread debate about the presence of PO-210 in cigarette smoke would have on public perception. In contrast to the general approach of "creating doubt about the health charges without having to deny it,"[4] the industry's strategy for handling the PO-210 controversy was to a take a vow of silence and avoid "waking a sleeping giant."[3]

Failed efforts to remove PO-210 from tobacco smoke convinced industry officials that it would never be technologically feasible on a production level. Although some tobacco company researchers genuinely believed that the amount of PO-210 in cigarette smoke was too small to be a major risk factor for lung cancer induction, this opinion was not shared by company lawyers. In their quest to decrease the companies' legal exposure, the lawyers advocated suppressing data that contested published reports on the amount of PO-210 in cigarette smoke, despite the favorable effect publication of such data might have had on the tobacco industry. The internal debate carried on for the better part of a decade, involved most cigarette manufacturers, and pitted tobacco researchers against tobacco lawyers. The lawyers prevailed.

The tobacco industry remains silent on the PO-210 issue, suggesting that it continues to fear public reaction. We found no mention of radioactive particles in tobacco and tobacco smoke on any of the major transnational tobacco companies' current Web sites that present smoking and health information aimed at consumers. We support a proposed new warning label on cigarettes: "Surgeon General's Warning: Cigarettes are a Major Source of Radiation Exposure."[98] This wording would capitalize on public concern over radiation exposure and increase the impact of cigarette warning labels. Health messages highlighting PO-210 as one of the known carcinogens in cigarettes could aid tobacco control efforts. ■

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References

1. Proctor RN. Puffing on polonium. *New York Times.* December 1, 2006:A31.
2. Broad WJ. Polonium, $22.50 plus tax. *New York Times.* December 3, 2006:sect4:1.
3. Eichorn P. Handwritten note to R.B Seligman. Philip Morris. June 2, 1978. Bates no. 1003725613. Available at: http://legacy.library.ucsf.edu/tid/evp08e00. Accessed October 31, 2007.
4. Panzer F. Roper proposal exhibit C-2. Philip Morris. May 1, 1975. Bates no. TIBU0001282. Available at: http://legacy.library.ucsf.edu/tid/cuo91f00. Accessed October 31, 2007.
5. Ciresi M, Walburn R, Sutton T. Decades of deceit: document discovery in the Minnesota tobacco litigation. *William Mitchell Law Rev.* 1999;25:477–566.
6. Malone RE, Balbach ED. Tobacco industry documents: treasure trove or quagmire? *Tob Control.* 2000;9:334–338.
7. Balbach E. Tobacco industry documents: comparing the Minnesota Depository and internet access. *Tob Control.* 2002;11:68–72.
8. Muggli ME, LeGresley E, Hurt RD. Big tobacco is watching: British American Tobacco's surveillance and information concealment at the Guildford Depository. *Lancet.* 2004;363:1812–1819.
9. Collin J, Lee K, Gilmore A. Unlocking the corporate documents of British American Tobacco: an invaluable global resource needs radically improved access. *Lancet* 2004;363:1746–1747.
10. Bero L. Implications of the tobacco industry documents for public health and policy. *Annu Rev Public Health.* 2003;24:267–288.

11. Tobacco company strategies to undermine tobacco control activities at the World Health Organization: the report of the committee of experts on tobacco industry documents. July 2000. Available at: http://repositories.cdlib.org/tc/whotcp/WHO7. Accessed November 4, 2007.

12. Muggli ME, Hurt RD, Blanke DD. Science for hire: a tobacco industry strategy to influence public opinion on secondhand smoke. *Nicotine Tob Res.* 2003;5:303–314.

13. Radford E, Hunt V. Polonium-210, a volatile radioelement in cigarettes. *Science.* 1964;143:247–249.

14. Winters T, DiFranza J. Radioactivity in cigarette smoke. *N Engl J Med.* 1982;306:364–365.

15. Wynder E, Hoffman D. *Tobacco and Tobacco Smoking.* New York, NY: Academic Press; 1967.

16. Yuille C, Berk H, Hull T. Lung cancer following polonium-210 inhalation in rats. *Radiat Res.* 1967; 31:760–774.

17. Little J, O'Toole W. Respiratory tract tumors in hamsters induced by benzopyrene and polonium-210 alpha radation. *Cancer Res.* 1974;34:3026–3039.

18. Kilthau G. Cancer risk in relation to radioactivity in tobacco. *Radiol Technol.* 1996;67:217–222.

19. Little J, Radford E, McCombs H. Distribution of polonium-210 in pulmonary tissues of cigarette smokers. *N Engl J Med.* 1965;273:1343–1351.

20. Azzam E, de Toledo S, Gooding T, Little J. Intercellular communication is involved in the bystander regulation of gene expression in human cells exposed to very low fluences of alpha particles. *Radiat Res.* 1998;150:497–504.

21. Holtzman R, Ilcewicz F. Lead-210 and polonium-210 in tissues of cigarette smokers. *Science.* 1966; 153:1259.

22. Radford E. Radioactivity in cigarette smoke [letter to the editor]. *N Engl J Med.* 1982;307(23):1449–1450.

23. American Cancer Society. Cancer facts and figures 2006. Available at: http://www.cancer.org. Accessed September 23, 2007.

24. World Health Organization. Cancer fact sheet. February 2006. Available at: http://www.who.int/mediacentre/factsheets/fs297/en/. Accessed January 13, 2007.

25. Hill C. Polonium-210 in man. *Nature.* 1965; 208:423–429.

26. Tso T, Harley N, Alexander L. Sources of lead-210 and polonium-210 in tobacco. *Science.* 1966;153: 880–883.

27. Tso T, Hallden N, Alexander L. Radium-226 and polonium-210 in leaf tobacco and tobacco soil. *Science.* 1964;146:1043–1044.

28. Marmorstein J. Lung cancer: is the increasing incidence due to radioactive polonium in cigarettes? *South Med J.* 1986;79:145–150.

29. Martell E. Radioactivity of tobacco trichomes and insoluble cigarette smoke particles. *Nature.* 1974; 249:215–217.

30. Martell E. Tobacco radioactivity and cancers in smokers. *Am Sci.* 1975;63:404–410.

31. Segura G. Polonium-210: a volatile radioelement in cigarettes, by Edward P. Radford Jr and Vilma R. Hunt. Philip Morris. January 1, 1964. Bates no. 1001881897. Available at: http://legacy.library.ucsf.edu/tid/bic38e00. Accessed October 31, 2007.

32. Parmele H. Letter to AW Spears. Lorillard. January 28, 1964. Bates no. 00073000. Available at: http://legacy.library.ucsf.edu/tid/qco99d00. Accessed October 31, 2007.

33. Homburger F. Letter to HB Parmele. Lorillard. March 6, 1964. Bates no. 01198031. Available at: http://legacy.library.ucsf.edu/tid/tav81e00. Accessed October 31, 2007.

34. Parmele H. Letter to F. Homburger. Lorillard. March 11, 1964. Bates no. 01195732. Available at: http://legacy.library.ucsf.edu/tid/kvv81e00. Accessed October 31, 2007.

35. Nystrom C. Comparison of polonium-210 activity in tobacco leaves grown inside (greenhouse) and outside (roof). R.J. Reynolds. July 13, 1964. Bates no. 502856669/6679. Available at: http://legacy.library.ucsf.edu/tid/hbz68d00. Accessed October 31, 2007.

36. Bellin S, Nystrom C, Sizemore N, Nielson E. Polonium-210 in tobacco. III. Further evidence that a major portion originates from atmospheric contamination of tobacco plants. R.J. Reynolds. October 10, 1964. Bates no. 500964169/4187. Available at: http://legacy.library.ucsf.edu/tid/gul59d00. Accessed October 31, 2007.

37. R.B. Richardson. Further investigations of polonium-210 in tobacco and smoke. British American Tobacco. January 15, 1985. Bates no. 101239428-101239437. Available at: http://bat.library.ucsf.edu/tid/nzx07a99. Accessed October 31, 2007.

38. Jenkins R, Osdene T, Segura G. The concentration of polonium-210 in tobacco and its distribution in smoke. Technical Report no. 284. Philip Morris. October 4, 1968. Bates no. 2012611302/1309. Available at: http://legacy.library.ucsf.edu/tid/txr46e00. Accessed October 31, 2007.

39. Ferguson R. Information on isotopes from natural decay of 238U in tobacco from R&D studies. Philip Morris. April 15, 1997. Bates no. 2060535064. Available at: http://legacy.library.ucsf.edu/tid/qlk13e00. Accessed October 31, 2007.

40. No Author. Copied to Farone W, Gannon W, Jenkins R, Osdene T, Wakeham H. Radiochemistry polonium. Philip Morris. April 15, 1977. Bates no. 1000256403. Available at: http://legacy.library.ucsf.edu/tid/emk84e00. Accessed October 31, 2007.

41. Osdene T. Year-end summary—1976 research. Philip Morris. December 20, 1976. Bates no. 1000743715. Available at: http://legacy.library.ucsf.edu/tid/hgx54e00. Accessed October 31, 2007.

42. Trial testimony of William Anthony Farone, PhD. September 25, 2001. *In Re: Tobacco Litigation (Medical Monitoring Cases) [Blankenship].* Bates no. FARONEW 092501PM. Available at: http://legacy.library.ucsf.edu/tid/jlg35a00; p1954–1955. Accessed October 31, 2007.

43. Mold J. Process for production of less noxious cigarettes available from Ipromarc SA. Liggett and Meyers. August 4, 1975. Bates no. lg0432302. Available at: http://legacy.library.ucsf.edu/tid/lvp47a00. Accessed October 31, 2007.

44. Mold J. Process for production of less noxious cigarettes available from Ipromarc SA. Liggett and Meyers. August 4, 1975. Bates no. lg0432304. Available at: http://legacy.library.ucsf.edu/tid/lvp47a00. Accessed October 31, 2007.

45. Trial testimony of William Anthony Farone, PhD. March 5, 1999. *Williams v Phillip Morris Inc.* Bates no. FARONEW030599AM. Available at: http://legacy.library.ucsf.edu/tid/vtn05a00. Accessed October 31, 2007.

46. Deposition of Martin L. Reynolds. March 27, 1997. *The State of Mississippi v Philip Morris et al.*; 100–103. Bates no. REYNOLDSM032797. Available at: http://legacy.library.ucsf.edu/tid/oas07a00. Accessed November 1, 2007.

47. Deskin R. Attachment B. Program/project summary and statues update. August 1986. R.J. Reynolds. Bates no. 506236142. Available at: http://legacy.library.ucsf.edu/tid/foh55a00. Accessed November 1, 2007.

48. Minnemeyer H, Schickedantz P. Twelfth annual review research department 860000. Lorillard. February 26, 1988. Bates no. 89517545. Available at: http://legacy.library.ucsf.edu/tid/fme30e00. Accessed November 1, 2007.

49. Trial testimony of Richard Allan Carchman, PhD. March 24, 1999. Bates no. CARCHMANR032499AM. *Engle v R.J. Reynolds Tobacco Co.* Available at: http://legacy.library.ucsf.edu/tid/lia85a00. Accessed October 31, 2007.

50. Trial testimony of William Anthony Farone, PhD. February 19, 2002. *Schwartz v Phillip Morris Inc.* Bates no. FARONEW021902PM. Available at: http://legacy.library.ucsf.edu/tid/aun05a00. Accessed October 31, 2007.

51. Jones S, George M. Jacobson idea—tourmaline filter for removal of polonium-210 from cigarette smoke. R.J. Reynolds. November 30, 1966. Bates no. 502422294. Available at: http://legacy.library.ucsf.edu/tid/ksa19d00. Accessed November 1, 2007.

52. Nielson E, Nystrom C. Polonium-210: failure of ion-exchange resin filters to selectively remove polonium-210 from cigarette smoke. R.J. Reynolds. October 25, 1967. Bates no. 500613602. Available at: http://legacy.library.ucsf.edu/tid/bhv69d00. Accessed November 1, 2007.

53. Horswell H. An examination of filter materials for the removal of polonium-210 from cigarette smoke. Brown and Williamson. June 21, 1968. Bates no. 650315307/5329. Available at: http://legacy.library.ucsf.edu/tid/upm00f00. Accessed November 1, 2007.

54. Norman V. Comments on recent news releases concerning lead-210 and polonium-210 in cigarette smoke. Liggett and Meyers. July 25, 1974. Bates no. 81151933/1935. Available at: http://legacy.library.ucsf.edu/tid/qzl41e00. Accessed November 1, 2007.

55. Trial testimony of Jerry Frank Whidby, PhD. February 28, 2002 [a.m., Vol. II]. *Schwartz v Philip Morris Inc.* Bates no. WHIDBYJ022802AMVOL2. Available at: http://legacy.library.ucsf.edu/tid/djy75a00. Accessed November 1, 2007.

56. Nystrom C, Nielson E. Test of tourmaline filter for the removal of polonium-210 from cigarette smoke. R.J. Reynolds. June 26, 1964. Bates no. 504913279. Available at: http://legacy.library.ucsf.edu/tid/szv35d00. Accessed November 1, 2007.

57. Horsewell H, Richardson R. Evaluation of copper treated filters with regard to the removal of polonium-210 from cigarette smoke laboratory report number

L190-R. British American Tobacco. May 24, 1966. Bates no. 105453541/3550. Available at: http://bat.library.ucsf.edu/tid/dhd94a99. Accessed November 1, 2007.

58. Richardson R, Horsewell H. Evaluation of copper treated filters with regard to the removal of polonium-210 from cigarette smoke laboratory report number L190-R. British American Tobacco. May 24, 1966. Bates no. 105453542. Available at: http://bat.library.ucsf.edu/tid/dhd94a99. Accessed November 1, 2007.

59. Philip Morris. Radiochemistry polonium. Philip Morris. April 15, 1977. Bates no. 1000256401/6404. Available at: http://legacy.library.ucsf.edu/tid/emk84e00. Accessed November 1, 2007.

60. Gannon W. 210PO manuscript. Philip Morris. May 30, 1978. Bates no. 1001839659. Available at: http://legacy.library.ucsf.edu/tid/jzu28e00. Accessed November 1, 2007.

61. Nystrom C. Comments on the Stauffer patent no. 4.194.514 for removal of radioactive lead and polonium from tobacco. R.J. Reynolds. March 5, 1982. Bates no. 503245607. Available at: http://legacy.library.ucsf.edu/tid/syc68d00. Accessed November 15, 2007.

62. Trial testimony of William Anthony Farone, PhD. September 25, 2001. *In Re: Tobacco Litigation (Medical Monitoring Cases) [Blankenship].* Bates no. FARONEW 092501AM. Available at: http://legacy.library.ucsf.edu/tid/klg35a00; p2103–2105. Accessed October 31, 2007.

63. Glantz S, Barnes D, Bero L, Hanauer P, Slade J. Looking through a keyhole at the tobacco industry: the Brown and Williamson documents. *JAMA* 1995; 274:219–224.

64. Hurt RD, Robertson CR. Prying open the door to the cigarette industry's secrets about nicotine—the Minnesota Tobacco Trial. *JAMA* 1998;280:1173–1181.

65. Guardino S, Friedman L, Daynard R. Remedies for document destruction: tales from the tobacco wars. *Va J Soc Policy Law.* 2004;12:1–60.

66. Guardino S, Daynard R. Tobacco industry lawyers as "disease vectors." *Tob Control.* 2007;16:224–228.

67. Racketeer Influenced and Corrupt Organizations Act. 18 USC §67 (1962) (c) (d).

68. *United States of America v Philip Morris USA Inc.*, 449 F.Supp.2d. 1, 801. (DC 2007). Available at: http://www.usdoj.gov/civil/cases/tobacco2/amended%20opinion.pdf. Accessed October 31, 2007.

69. Management and Legal Supervision and Control of R&D Activities R.J. Reynolds. December 1985. Bates no. 519198805 and 8814. Available at: http://legacy.library.ucsf.edu/tid/zrb77a00. Accessed November 2, 2007.

70. Debevoise and Plimpton. Special project # 48. Lorillard. December 31, 1992. Bates no. 92613989-91. Available at: http://legacy.library.ucsf.edu/tid/yxz95a00. Accessed November 2, 2007.

71. Final Mem. Op. *United States of America v Philip Morris USA Inc,* case no. 99-CV-02496 (GK) at paragraph 238, p 119. Available at: http://www.usdoj.gov/civil/cases/tobacco2/amended%20opinion.pdf. Accessed October 31, 2007.

72. Frisch A. [Memo to Cathy Ellis]. Philip Morris. September 23, 1997. Bates no. 2060534958. Available at: http://legacy.library.ucsf.edu/tid/skk13e00. Accessed November 2, 2007.

73. Frisch A. External publication internal activity. Philip Morris. Est date: September 23, 1997. Bates no. 2060534959/4962. Available at: http://legacy.library.ucsf.edu/tid/knn05c00. Accessed November 2, 2007.

74. No author. Review of Philip Morris scientific documents. Philip Morris. January 1, 1985. Bates no. 2023033879. Available at: http://tobaccodocuments.org/bliley_pm/23979.html. Accessed November 2, 2007.

75. Jenkins R, Comes R, Core M, Osdene T, Tucci R, Williamson T. Naturally occurring 222 radon daughters in tobacco and smoke condensate. Philip Morris. May 5, 1978. Bates no. 2012601308/1333. Available at: http://legacy.library.ucsf.edu/tid/inj24e00. Accessed November 2, 2007.

76. Seligman R. Publication on 210PO in cigarette smoke. Philip Morris. June 8, 1978. Bates no. 100372 5612. Available at: http://legacy.library.ucsf.edu/tid/srs87e00. Accessed November 2, 2007.

77. Thomson RN. PO 210 manuscript. Philip Morris. May 24, 1978. Bates no. 1001839599/9601. Available at: http://legacy.library.ucsf.edu/tid/pzu28e00. Accessed November 2, 2007.

78. Seligman R. America's electric energy companies' ad. Philip Morris. January 18, 1990. Bates no. 100372 5602. Available at: http://legacy.library.ucsf.edu/tid/rrs87e00. Accessed November 2, 2007.

79. DGF. Discussion with TC Tso USDA. British American Tobacco. July 27, 1981. Bates no. 100431374. Available at: http://bat.library.ucsf.edu/tid/gpg54a99. Accessed November 2, 2007.

80. Jenkins R. Review of manuscript by EA Martell. Philip Morris. June 11, 1982. Bates no. 2012601249. Available at: http://legacy.library.ucsf.edu/tid/kur46e00. Accessed November 2, 2007.

81. Frisch A. External publication internal activity. Philip Morris. Est date: September 23, 1997. Bates no. 2060534968. Available at: http://legacy.library.ucsf.edu/tid/knn05c00. Accessed: November 2, 2007.

82. No author. [Handwritten notes from Cathy Ellis's files.] Philip Morris. September 23, 1997. Bates no. 2060534957. Availble at: http://legacy.library.ucsf.edu/tid/xkk13e00. Accessed November 2, 2007.

83. R.B. Richardson [Note regarding polonium-210]. British American Tobacco. July 1985. Bates no. 10123 9425. Available at: http://bat.library.ucsf.edu/tid/lzx07a99. Accessed November 1, 2007.

84. R.B. Richardson. Protocol for the measurement of polonium-210 in tobacco and in smoke condensate. British American Tobacco. February 11, 1983. Bates no. 101239465-101239466. Available at: http://bat.library.ucsf.edu/tid/vzx07a99. Accessed November 2, 2007.

85. Richardson RB. Further investigations of polonium-210 in tobacco and smoke. British American Tobacco. November 5, 1985. Bates no. 101239428-101239437. Available at: http://bat.library.ucsf.edu/tid/nzx07a99. Accessed November 2, 2007.

86. Osdene T. Polonium-210. Philip Morris. October 13, 1982. Bates no. 2060535055. Available at: http://legacy.library.ucsf.edu/tid/olk13e00. Accessed November 2, 2007.

87. Segura G, Varsel C. Summaries of meetings with Dr Wolf, 660718. Philip Morris. August 9, 1966. Bates no. 2026432357. Available at: http://legacy.library.ucsf.edu/tid/hub15e00. Accessed November 2, 2007.

88. Tarves J. Consultant agreement with Dr Alfred P. Wolf. Bates no. 2026432351. Philip Morris. July 22, 1966. Available at: http://legacy.library.ucsf.edu/tid/mub15e00. Accessed November 2, 2007.

89. Wolf A. No title. Philip Morris. June 21, 1966. Bates no. 1001937221/7222. Available at: http://legacy.library.ucsf.edu/tid/ajc64e00. Accessed November 2, 2007.

90. Wolf A. Report on trip to Phillip Morris research center 661004. Philip Morris. October 20, 1966. Bates no. 1000831889. Available at: http://legacy.library.ucsf.edu/tid/tyo28e00. Accessed November 2, 2007.

91. Deposition of Geoffrey Bible. August 21, 1997. *The State of Florida et al v American Tobacco et al.* Bates no. BIBLEG082197. Available at: http://legacy.library.ucsf.edu/tid/mna85a00. Accessed November 6, 2007.

92. Trial testimony of William Anthony Farone, PhD. March 1, 1999. *Local No. 17 Bridge & Iron Workers Insurance Fund v Phillip Morris Inc.* Bates no. FARONEW 030199. Available at: http://legacy.library.ucsf.edu/tid/ytn05a00; p271. Accessed October 31, 2007.

93. Deposition of Thomas S. Osdene, PhD. June 16, 1997. *The State of Minnesota et al v Philip Morris et al.* Bates no. OSDENET061697. Available at: http://legacy.library.ucsf.edu/tid/gzy75a00. Accessed November 6, 2007.

94. Deposition of Nicholas George Brookes. August 9, 1997 [p.m.]. *Texas v American Tobacco Company et al.* Bates no. BROOKESN080997PM. Available at: http://legacy.library.ucsf.edu/tid/bla85a00. Accessed November 6, 2007.

95. No author. Expert witness deposition outline—tobacco smoke constituents. Brown and Williamson. No date. Bates no. 682624165. Available at: http://legacy.library.ucsf.edu/tid/rjx95a00. Accessed November 2, 2007.

96. Sizemore N, Nystrom C. Polonium-210 in tobacco and tobacco smoke. R.J. Reynolds. June 8, 1964. Bates no. 500986431. Available at: http://legacy.library.ucsf.edu/tid/vbk59d00. Accessed November 2, 2007.

97. Trial testimony of Richard Allan Carchman, PhD. March 9, 1999. *Iron Workers Local Union No. 17 Insurance Fund v Philip Morris et al.* Bates no. 2078003228-29. Available at: http://legacy.library.ucsf.edu/tid/jxx75c00. Accessed November 2, 2007.

98. Woods M. Radiation warning urged for cigarettes. *Chatanooga Times Free Press.* May 17, 2000;A3.